# DO GHOST NET ENTANGLEMENT RATES VARY AMONG SEA TURTLE SPECIES? COMPARATIVE ANALYSIS OF REGIONAL STUDIES PROVIDES INSIGHT

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*ABSTRACT: The impacts ghost nets (fishing nets that have been lost, abandoned, or carelessly discarded by fishermen) have on marine ecosystems is beginning to be understood as previous instrumental limitations has made data collection difficult. Currently, it is known that ghost nets entangle sea turtles, reducing their population sizes and leading to faster spread of disease/ scarcities in marine resources. With more advanced technology now available, conducting further research on ghost nets and sea turtle entanglements becomes critical as more accurate data provides better influences on policy decisions and fishing net regulations aimed to protect these endangered keystone species. For these reasons, I inquired whether different sea turtle species (olive ridley, leatherback, green, hawksbill, Kemp's ridley, flatback, and loggerhead) are entangled in ghost nets at different rates by comparing and evaluating the findings of five original research papers. Data that has been collected for 14 years by researchers and citizen scientists on the number of sea turtle entanglements and ghost nets across four regions was used to calculate and compare entanglement rates for each species (measured in individuals per year). A total of 9,989 ghost nets both washed ashore and drifted in oceans entangled 1,374 sea turtles across all species and locations. Olive ridleys had the highest rate of entanglement at 132 and 80 individuals per year in the Maldives and Northern Australia, respectively. In Northern Peru where olive ridleys aren't native, green sea turtles had the highest rate at 109 individuals entangled per year. Valencia had no observed olive ridleys entanglements since this species does not live here, but there were a reported 47 loggerheads annually entangled here, the highest rate among the present species in this region. It was interesting to observe that flatback sea turtles were only present in Northern Australia, and they had an entanglement rate of less than 5 individuals per year. What these findings suggest is that the impact of ghost nets on global sea turtle populations is larger than previously expected, with species that are entangled more frequently (like the olive ridley) being at an increased risk of becoming endangered. In order to more accurately estimate future sea turtle populations, more research and data collection needs to be performed.*

*Key words: Ghost net, entanglement, sea turtle, olive ridley, human impact, conservation*

## Introduction

Sea turtles are a keystone species that play a critical role in maintaining ecosystems by controlling populations of algae, sponges, and seagrass (Allen et al. 2007). Without them, coral reef communities would not function at optimal health and be able to sustain an abundance of diverse organisms through their constant cycling of nutrients between the ocean and beaches. Globally, there are seven species of sea turtle: flatback, green, hawksbill, leatherback, loggerhead, Kemp's ridley, and olive ridley. It is estimated that more than 3 billion people of the world's population rely on ocean ecosystems for their income and food/medicine sources (Ho et al. 2016). Human activity like poor fishing techniques and net monitoring increases the risk for sea turtles to become injured or entangled within equipment, reducing the productivity of the marine ecosystems. To protect these endangered species most effectively, it is important to gain a better understanding of the scale of impact ghost net fishing has on sea turtles.

It is known that inclement weather, equipment snagging, human error, and purposely abandoning equipment are factors contributing to the formation of ghost gear (fishing nets, trawlers, traps, pots) (Masroori et al. 2004). Richardson et al. (2018) estimates that an annual average of 640,000 tons of fishing gear are introduced to the oceans. With demand for seafood harvest outpacing consumption at a global average rate of 20kg of seafood per person per year (Richter and Klockner 2017), a rise in fishing activities to sustain this demand and, consequently, the introduction of more fishing gear into oceans is expected. While there has been some research conducted on ghost gear, what remains unclear are the effects ghost nets have on sea turtle populations.

Previous research conducted across the Maldives (Stelfox et al. 2019), Northern Peru (Pingo et al. 2017), Australia (Wilcox et al. 2015), and Valencia (Tomás et al. 2008) have found a combined total of over 1,300 sea turtles entangled in roughly 10,000 ghost nets. Based on their data, these studies suggest that sea turtles are more susceptible to becoming entangled in ghost nets since other animals observed like sharks, rays, fish, and dugongs accounted for 24% of the entanglements (Wilcox et al. 2015). Additionally, factors such as geographical differences in oceanic currents, climate, and fishing practices have been suggested to contribute to regional differences in sea turtle entanglements (Stelfox et al. 2019). What remains unknown is whether certain sea turtle species are more likely to become entangled in ghost nets due to factors like population sizes, migration patterns, and behavior with nets. Additionally, gaps in technology advancements and methodological difficulties in tracking ghost nets make it challenging to assess and quantify the number of nets present in a location (Stelfox et al. 2019).

This paper focuses on discovering how frequently different sea turtle species become entangled in ghost nets and if certain species have higher rates of entanglement. A comparative approach answers this by analyzing and evaluating the findings of five original peer-reviewed studies set in four distinct locations: Northern Peru, Australia, the Maldives, and Valencia. Data presented on the number of entanglements and study length were used in calculating entanglement rates per species in each region. I used the resulting numbers in evaluating and determining which species had higher entanglement rates. The results I have found are useful for identifying and monitoring sea turtle species at highest risk of becoming endangered from ghost net fishing, and helping guide policies and regulations to protect them.

## Methods

### Finding Original Research Articles

To effectively locate relevant articles, I used the databases Web of Science and Academic Search Complete to enter the following keywords using Boolean operators: ("bycatch" and "fishing nets"), ("sea turtles" and fishing nets"), and (("sea turtle" and "entanglement") and "human impact"). Once I found relevant articles, the keywords they listed were also used in the databases. These included "strandings", "catch rate", "human impact", "marine biology", and "fishery gear".

For every article selected, I skimmed through the abstract, methods, and results sections to determine if original research was performed. Articles that were an analysis or review of data from original research had their references checked to find the original research publication. I also selected publications by their period of research. Studies published more than 13 years ago and studies that collected data for longer than 14 years were not included in my analysis to prevent my data from being skewed. Not many research studies are conducted for this long, so choosing this time frame allowed me to work with a realistic representation of long-term effects in the selected regions. Additionally, tools used in data collection have advanced in recent years, so selecting studies conducted and published around the same time reduced instrumentation variability and the uncertainty range of collected data. Publications in which fishing nets were actively used and monitored by fishermen were disregarded as they do not fit the definition of a ghost net. Similarly, articles that studied the impacts of other ghost gear like lobster traps and pots were also excluded from my data analysis. Articles that met my criteria and were used in my analysis include the following: Pingo et al. (2017), Stelfox et al. (2019), Stelfox et al. (2020), Tomás et al. (2008), and Wilcox et al. (2015).

### Data analysis

Studies that reported the number of sea turtles entangled per species in percentages were recalculated to the exact number of individuals (rounded to the nearest whole number) by multiplying the percentage by the total number of entanglements reported (see Equation 1). Articles like those published by Wilcox et al. (2015) which also reported other animal entanglements in percentages had the percentage of sea turtle entanglements multiplied by the total number of animals reported to determine how many of the entanglements pertained to sea turtles. The total number of sea turtles entangled in each study was divided by the length of time the data was collected to determine the average annual rate of entanglement in each location (see Equation 2). Similar calculations were made to determine the annual rate of entanglement per species in each location.

Equation 1:

Converting percentages of sea turtles entangled into a whole number

98.1% loggerheads = 0.981 loggerheads

0.981 loggerheads * 619 total sea turtles recorded = 607.2= ~607 loggerheads entangled

Equation 2:

Calculating the rate of entanglement per species (equation also used to calculate rate of total entanglements)

$$\frac{607\ loggerheads\ entangled}{13\ year\ study\ period} = 46.69 = \sim 47 \text{ loggerhead entanglements per year}$$

### Results

In the first of two separate studies done in the Maldives (1-year study period), a total of 177 ghost nets were reported (Stelfox et al. 2020) with an average rate of 137 total sea turtles entangled per year. In the second study done in the Maldives (5-year study period), 1,069 ghost nets reported entangling 377 sea turtles (Stelfox et al. 2019) with an average rate of 75 sea turtle entanglements per year. The Northern Peru region had a rate of 113 annual sea turtle entanglements with a total of 53 ghost nets identified (Pingo et al. 2017). In Valencia, a total 619 sea turtles wound up entangled at a rate of 48 turtles per year. The number of reported ghost nets was not specified for this region (Tomás et al. 2008). Finally, in Northern Australia, a total of 8,690 nets were reported with 137 sea turtles entangled (Wilcox et al. 2015). The rate for sea turtle entanglements was 20 per year.

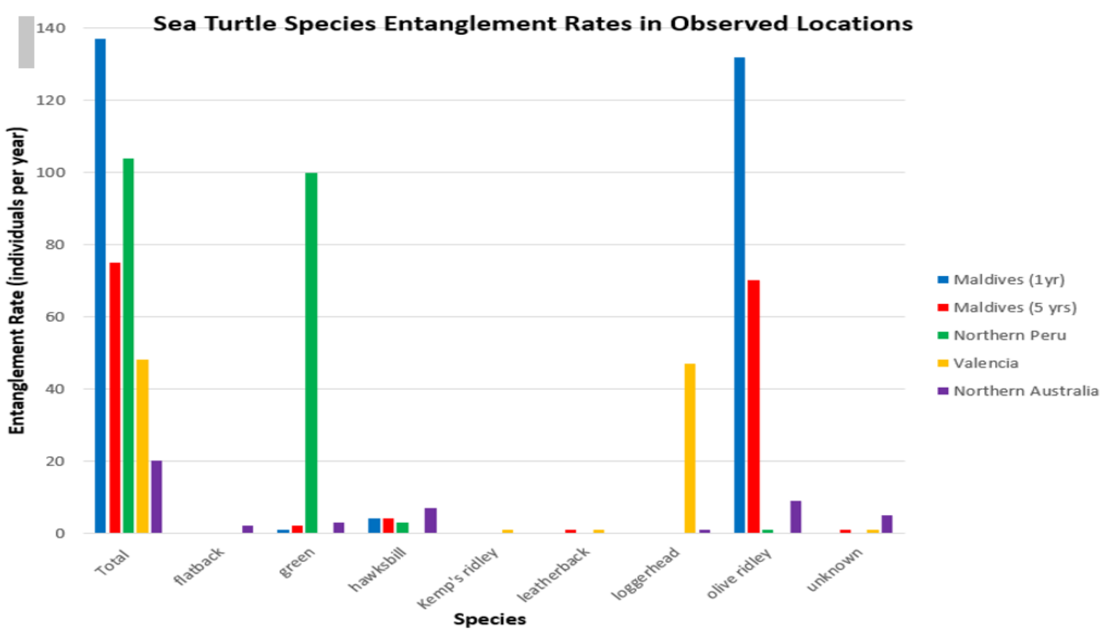
In the 1-year study in the Maldives, olive ridleys had the highest rate of entanglement among the species observed at a rate of 132 per year, and green turtles had the least with only one entanglement per year (Figure 1). In the 5-year study of the same location, olive ridleys also had the highest rate at 70 entanglements annually. In Northern Peru, where olive ridleys are not native, green turtles had the highest rate of entanglement at 109 individuals annually (Pingo et al. 2017). Valencia also did not have olive ridleys native to their region. Here, loggerheads had the highest rate of entanglement among the species observed at

47 individuals per year. Turtles species labeled as unknown in Figure 1 were not able to be identified in the observed locations during the studies because only skeletal remains of the sea turtles were observed in the nets. Table 1 provides a summary of the research location, number of ghost nets reported, total number of entanglements, and sea turtle species native to the regions.

Table 1:
*Summary of all locations studied, number of identified ghost nets, total sea turtle entanglements, and species inhabiting each location.*

| Research Location | Number of Ghost Nets Identified | Total Entanglements | Species Inhabiting Location | Species Not Inhabiting Location |
|---|---|---|---|---|
| Maldives (1-year study) | 177 | 137 | green, hawksbill, leatherback, loggerhead, olive ridley | flatback, Kemp's ridley |
| Maldives (5-year study) | 1,069 | 377 | green, hawksbill, leatherback, loggerhead, olive ridley | flatback, Kemp's ridley |
| Northern Peru | 53 | 104 | green, hawksbill, leatherback, loggerhead, olive ridley | flatback, Kemp's ridley |
| Valencia | Not specified | 619 | green, hawksbill, Kemp's ridley, leatherback, loggerhead, | flatback, olive ridley |
| Northern Australia | 8,690 | 137 | flatback, green, hawksbill, leatherback, loggerhead, olive ridley | Kemp's ridley |

Figure 1:
*Rates of entanglement for sea turtles species in each studied region*



## Discussion

The findings of my paper suggest that impacts of ghost net fishing on sea turtle populations are larger than previously expected. The comparative approach used in evaluating the five original research publications quantified prior general understandings, and also highlighted that the impact of ghost net fishing activity is not geographically isolated to one location, but is affecting marine ecosystems across the world as evidenced by the 4 distinct regions I chose to evaluate.

Olive ridleys in the Maldives and Australia, green turtles in Northern Peru, and loggerheads in Valencia community were the species most impacted by ghost nets as they had the highest entanglement rates (individuals/year) per location (Figure 1). What this suggests is that these species are at an increased risk of becoming endangered if the rate of introduction of new ghost nets remains constant or increases in each location. Reasons why these regions saw different species being affected include, but are not limited to, not all species observed in each region being native across all research locations, the local weather, tide, and current patterns affecting speeds in which ghost nets are transported throughout the waters, and different species expressing different behaviors (such as mistaking nets for food and swimming towards them).

It is important to note that the methodologies and instrumentation used among the studies in identifying and tracking ghost nets is a new technology still being developed (Stelfox et al. 2020). With this limitation, this suggests for the results that the 9,989 total ghost nets identified across all locations (Table 1) is underreported and that the true value may be significantly higher than the reported value. This limitation affects the calculated rates of entanglement for each species, as unaccounted nets can't be analyzed for entanglements. Additionally, some of the selected studies also observed entangled sea turtles that were unable to be identified as only remnants of bones and shells were found in the nets (Stelfox et al. 2019). Although this is an indication that entanglements are still occurring in these regions and that the ghost nets continue to pose an immediate threat to sea turtle wellbeing, it doesn't provide accurate data on the total number of individuals affected per species. This, again, limits our capabilities of understanding the scope of impact and further suggestions for what can be done to protect these species.

Despite the limitations, this provides an excellent foundation for future research to be conducted. Studies aimed at discovering whether ghost nets found on beaches or in the ocean have a greater influence on the rates of sea turtle entanglement, and if genetic testing can be used to identify the species from which bone and shell fragments originated will improve the accuracy of data being reported on sea turtle entanglements. This will enable us to make better informed suggestions for policies and actions taken towards protecting the wellbeing of both the sea turtle species and the ecosystems in which they live.

Florida has already implemented a policy as of 1995 entitled the Florida Net Ban Amendment that restricted the types of nets that fishermen can use and ensures that they actively are tending to the nets during their time out on the water and has shown to be successful (Adimey et al. 2014). Adimey et al. in 2014 reported that entanglement incidents for sea turtles was minimal and remained at a consistently low rate since the implementation of the policy, suggesting that policies are an effective measure towards protecting sea turtles. Suggestions for further actions to reducing the number of ghost nets introduced into our oceans and the number of entanglements include continuing to monitor and enforce already existing environmental policies and regulations, improving the durability of nets currently being used, and adding visible lights to the ends of the nets to detract sea turtles (Wilcox et al. 2015).

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